Chapter 6

Summary of Contributions

The goal of this thesis was to develop a method that enables autonomous mobile robots to localize themselves on a soccer playing field by perceiving the field lines with an omni-directional vision system. In particular, the goal was to achieve real-time recognition of shape-based features like the center circle, corners and T-junctions.

Besides this overall goal - the achievement of which was demonstrated at the world championships of the RoboCup MidSize league in 2004 - several advancements evolved from its pursuit:

- The first is a new algorithm which is able to track large homogeneous regions very efficiently. It is able to track several regions at the same time and to extract their boundary contours. The efficiency is accomplished by not processing the entire images but concentrating on parts where regions are expected. The algorithm exploits the fact that corresponding regions in successive images often overlap and it extends the region growing paradigm: Tracking is accomplished by alternating shrinking and growing. This idea is new and very general. A whole class of algorithms can be derived from it and they are not restricted to image processing. When solutions for a problem have to be computed successively, where the framework of the problem changes continuously in time, the idea is to reduce an already computed solution to an intersection, and to derive the new solution from the reduced one.

  In its concrete application for tracking regions we have shown that the algorithm outperforms existing solutions. The algorithm not only tracks the regions, but also yields their boundary contours. These can be used to apply local detectors in order to find features or objects close to the contours. The contours are given as lists of

points and tangent, and normal directions can easily and efficiently be calculated. Thus, feature detectors can be applied very selectively and they have to be applied at a few locations only. For instance, when searching for edges, a detector which responds to edges having a predefined direction can be used.

The method also exposes a useful interface for higher level algorithms. For instance, visual attention can be implemented by controlling which regions should be tracked. Here the primary issue is that when excluding a region from tracking, the algorithm is much faster, since less pixels are accessed in the images. Another interface is the extracted boundary contour. Since the algorithm is based on region growing, connected boundaries are guaranteed. The boundary can serve as a base for recognition of objects and movements or as a reference into the images. In RoboCup for instance, we track the regions of the green playing field and the boundary helps us to find other objects on the playing field. This is because all objects like the ball and other robots being on the playing field are next to the green regions in the images. Therefore their boundaries can be used as a reference into the image where to search for the objects, and they can be rapidly detected.

- The second contribution builds up on the first. It was shown how the region tracking algorithm can be used to extract the field lines of the RoboCup playing field and an efficient algorithm was described, which is able to recognize 6 different shape-based features in real-time. The recognition of further features can easily be integrated in the framework. To the knowledge of the author it is the first system that allows robust real-time recognition of such a large amount of complex features, with all the processing running on a single Pentium III 900 MHz processor. Besides the strengthes of the approach we have also described its weaknesses and possibilities for further research were indicated.

- Furthermore, it was shown how the feature-recognition process is combined with odometric information and a relative matching method in a three-layered localization framework.

- Here, the relative matching method is also a new contribution. It uses a precalculated force-field to register perceived field-lines to a global model of the playing field. The approach, which is meanwhile known as the "MATRIX"-method has been adapted by several other teams in RoboCup.